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FLO 1/14

See Distribution

7 April 2015

ACCIDENT AT *UK MILITARY RANGE SPRING* 2014

Redacted version for public release – redactions indicated by *italic text*

Introduction

1. Following reports of an accident involving a breech explosion at *UK Military Range* about *time* on *Saturday in Spring* 2014, the NRA was informed[1] that MoD Land Accident Investigation Team (LAIT) did not wish to investigate and that MoD requested that the NRA carry out an investigation in accordance with the NRA / MoD agreement for use of ranges by civilian clubs.

2. CE NRA tasked the NRA Firearms Manager (FM) to investigate. *FM* is a *FM qualifications and experience redacted*. *FM* travelled to *UK Military location* to commence the investigation on *Accident +4 days*, and between then and *Accident +6 days* viewed and searched the range, made contact with the Safety Officer for *UK Military location* and with *Police Force* who had taken possession of the firearm and ammunition following the accident, interviewed the firer and the RCO, collected copies of documents and collected the rifle and ammunition for technical analysis. Subsequently, the firearm and ammunition were examined informally at Bisley, as a result of which formal technical reports from recognised experts were sought. *FM* corresponded and discussed organisational and administrative issues arising with various parties. Some of those issues were addressed in an interim report and are recorded here, others are addressed here for the first time.

3. An initial report was distributed[2] shortly after the accident, and a second interim report was distributed[3] *later*. This letter is the final report of the investigation.

Circumstances

4. *Rifle Club A (RCA)*, with visitors *Rifle Club B (RCB)*, were shooting from the *firing point*[4] on the *Range* at *UK Military location,* under the supervision of *Mr C* (an NRA qualified RCO).

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[1] email DIO SD Trg-HQ Trg Safety to NRA Chief Executive
[2] NRA FLO 1/14 dated *Accident +11 days*
[3] NRA FLO 1/14 dated *Accident + 11 weeks*
[4] Enclosure 1 Photoset 1 – *redacted version for publication*

Accident

5. The accident happened when *Mr D*, a member of *RCB*, was firing his Krag-Jorgensen rifle[5] from the standing position in the right-hand side of the No1 fire pit[6] using home loaded 6.5x55 ammunition.

6. Accident Cause. The immediate cause of the accident was the rupture of the cartridge case on firing the fourth shot of a series, which released hot high pressure propellant gases into the rifle action, leading to catastrophic failure of the receiver forward ring[7]. The threaded portion of the receiver broke into at least 3 pieces and detached completely from the rest of the action, the extractor claw and a portion of the extractor arm detached, the entire left side of the action above the magazine access port distorted and failed at the rear of the magazine port. The barrel was driven forward several inches clear of the action, and the woodwork shattered around the receiver area. Metallic fragments and wood splinters were ejected at high speed in several directions[8]. Not all parts of the firearm have been recovered.

7. Injuries.

   a. *D* suffered injuries *medical information redacted.*

   b. Mr *E*, who was sharing No 1 fire pit with *D*, *medical information redacted.*

   c. Mr *F*, who was standing behind and to the right of No1 fire pit observing the operation of the Krag-Jorgensen, *medical information redacted.*

   All three casualties were taken to *Medical Facility* in accordance with the medical evacuation plan in *RCA*s RASP. Because of the remoteness of *UK Military location,* a decision was taken to evacuate by private car rather than wait for an ambulance. *D* and *F* both underwent more or less immediate surgery. *Medical information redacted. E* was treated as an outpatient. *Medical information redacted.*

8. Damage to Military Property. Nil.

9. Damage to Civilian Property. The rifle was transferred to NRA staff on *Accident + 6 days*, along with unfired ammunition and fired cases from the batch in use. The rifle is essentially destroyed, *detail redacted*. The body of the failed case remains stuck in the breech.

Reporting

10. Initial reports were made by telephone and in person to Range Control on the day of the accident. The NRA were advised by telephone on Monday *Accident + 2 days*. The RCO issued a written Incident Report[9] on *Accident + 3 days*.

Analysis – Rules

11. Redacted

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[5] Enclosure 1 photograph 2
[6] Enclosure 1 Photograph 3
[7] Enclosure 1 Photograph 4
[8] Enclosure 1 Photoset 5
[9] Enclosure 2 *not included in redacted version*

Analysis - Technical

Ammunition

12. The remaining ammunition (41 rounds) and fired cases (2) were transferred to *NRA Appointed Professional Expert (NRA-PE)* for examination. *NRA-PE qualifications and competencies redacted. NRA-PE* formal report has been delayed by illness. The following points of significance are extracted from *NRA-PE* initial report and conversations[10], with explanatory notes following each point:

    a. *Detail redacted*

    b. The 10 rounds dismantled were all at most 2/3 full of propellant.

        Note: The powder removed from 10 cartridges weighed 340.6gr and had a volume of 22ml[11]. Useful case capacity for a 6.5x55 case is quoted as 3.68 ml[12], thus the mean proportion of case volume taken by the propellant in the 10 cases dismantled was 0.60 . It has been observed[13] that too little powder of a slow burning variety can in rare cases cause excessive pressure. The powder used in this accident is noted by *D*, in the lid of the ammunition box[14], to be Accurate 2520, which is a relatively slow burning rifle powder. The powder removed is consistent in appearance with a sample of Accurate 2520. *D* includes in his written submission[15] that the powder is Lovex D073.6. As retailers of powder, the NRA is aware that the Lovex product and the Accurate product are the same powder, and both designations appear on the retail container. The mechanism by which excess pressure might arise from a reduced charge is not technically understood. One of the conditions quoted is that the reduced charge must be 25% to 35% under normal. Since a normal load is typically about 80% of case volume, the mean load provided here (60/80 = .75) is on the limit that writers suggest is necessary for this condition to be of significance. Given that is a mean, it is likely that about half the loads were smaller than the mean, taking the volumetric proportion into the critical range.

    c. Several cartridges have grossly deformed necks and/or shoulders.

        Note: The deformations, at least one of which is clearly visible by eye[16] are indicative of improper setting or operation of the equipment at one or more stages of the reloading process. *Detail redacted*

    d. *Detail redacted*

13. *Detail redacted. NRA-PE* concludes from the condition of the recovered unfired ammunition, as described and commented above, that:

    - *Detail redacted* case sizing
    - *Detail redacted* cartridge case length
    - *Detail redacted*

    are likely to have been significant contributing factors in this incident.

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[10] Email *NRAPE* to *FM* 24 January 2105 20:54
[11] *Process detail redacted*
[12] Richard Lee, *Modern Reloading*, 2nd edn, at p264
[13] eg Richard Lee, *Modern Reloading* 2nd edn, at p35
[14] Enclosure 1 Photograph 6
[15] Enclosure 3 *not included in redacted version*
[16] Enclosure 1 Photograph 7

Rifle

14. *D* states[17] that the rifle was brought to the UK by a Norwegian rifleman temporarily resident. *D* purchased it *detail redacted* when the owner returned to Norway in the 1960s. *D* understands that the rifle was rebarreled in the 1950s to convert it from a military weapon to a match-grade firearm for use in the biathalon event as staged in the Winter Olympics. *D* states that no work other than cleaning and routine maintenance has been carried out on the rifle since it has been in his possession, and that up to the accident the rifle had been in use for target shooting without any malfunction throughout his period of ownership.

15. Despite extensive searches by eye and using metal detecting equipment one section of the receiver ring, in an unknown number of pieces, was not recovered and presumably remains on the range. The firearm was subject to a preliminary examination on *Accident + 13 days* at Bisley, from which it was concluded that formal technical examination was necessary. The rifle and one fired case were transferred to *Laboratory at Scientific Institute (LSI)*. Dr *G, qualification redacted*, carried out a technical examination[18]. The following points are extracted from *G*'s report:

    a. The serial number and combination of these marks indicates that this rifle was originally from a series of rifles produced for the military at Steyr in 1897. Furthermore, the 'M P' monogram was the inspection mark of Jakob Maximillian Gran Paaske, who was head of the Norwegian inspection team at the Steyr factory between 1896-97[19].

    b. The barrel was not that originally fitted to this firearm and I understand that it had been replaced sometime circa 1950[20].

    c. Markings were also present on the barrel … 'YY 12' indicated the steel producer and was seen on barrels made between 1948-50. Furthermore, the 'A' monogram was the inspection mark of Halfdan Alstad, who worked at Kongsberg between 1945-50. It therefore suggests this barrel was manufactured at Kongsberg between 1948-1950[21].

    d. I understand that thousands of these match-grade barrels were produced at Kongsberg for the conversion of Krag-Jorgesen rifles[22]. However, these conversions were not always done by professional gunsmiths to high standards, which led to a series of catastrophic rifle failures in the 1950s[23].

    e. Macroscopic examination of the front face of the left side of the receiver ring showed strike marks visible on the first screw thread, as shown in Figure 7(a). These marks extended onto the top surface of the second thread producing coherent striations, as shown in Figure 7(b). These strike marks appeared to have been created by a flat faced object with straight sides, such as a screw driver tip or punch, and due to the coherence of the striations between screw threads they could not have been deposited when a barrel was fitted into the receiver ring[24].

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[17] Enclosure 5 *not included in redacted version*
[18] Enclosure 6 - *LSI* report of 16 February 2015 – redacted version
[19] *LSI* report at para 7
[20] *LSI* report at para 3
[21] *LSI* report, paras 9 and 10
[22] This and other information sourced by *G* from *Norske Militærgeværer etter 1867*, Karl Egil Hanevik, ISBN 82-993143-1-3.
[23] *LSI* report para 11
[24] *LSI* report para 16

f. Closer inspection of the screw threads on the receiver ring sections indicate that the first thread from the front to have been partially removed at some time, reducing its thickness by approximately half, as shown in Figure 8. Furthermore, numerous cut marks were visible on subsequent thread walls, which may have been as a result of attempts to alter the thread width or depth, shown in Figure 9[25].

g. …on the exterior surface of the left side and lower receiver ring sections were a series of uniform impressed marks, as shown in Figure 10. These marks may have been the result of this area being struck by another object or due to compression by another surface, such as being clamped in a vice or similar holding device. The presence of these marks may indicate that alterations have been performed on the rifle action at some time and the work may have been undertaken by an inexperienced or amateur gunsmith[26].

h. **No definite cause of failure could be established**[27].

i. From the parts recovered, the most likely mode of fracture was cleavage as a result of a single overload event. However, as the top section of the receiver ring was not recovered after the incident it is not possible to exclude that this section could have contained evidence of a flaw that could have initiated the failure of the rifle action[28].

j. It was observed that cuts were present in the walls of the screw threads in the receiver ring. It cannot be excluded that one or more of these could have acted as a crack initiation site, as demonstrated by the presence of a secondary crack emanating from one of these cuts on the left side of the receiver ring[29].

[25] *LSI* report para 17
[26] *LSI* report paras 18 and 19
[27] *LSI* report para 33
[28] *LSI* report, at para 29
[29] *LSI* report, at para 31

Analysis - Organisational

16. From the technical analysis it is obvious that organisational factors did not contribute to the chain of events resulting in the accident. However, it is normal in investigating such occurrences to consider the processes, procedures and actions leading up to and in the aftermath of the accident.

Status of Clubs and Participants

17. It has been determined that *RCA* was properly organised, insured and affiliated to permit use of MoD ranges. It has been determined that the individuals involved held appropriate Shooter Competency Certificates or valid RCO qualifications as appropriate to their roles. Evidence from *C*[30] (the RCO) forwarded both directly and with numerous other items[31] by *MoD Employee* (the Training Safety Officer for *UK Military location*) shows that the actual running of the range up to the accident was in accordance with orders and procedures.

Organisational Anomalies

Range booking and sharing.

18. *Discussion redacted.*

Actions of the RCO.

19. After the accident, *C* became concerned that, despite his instructions, interested bystanders might interfere with the firearm or ammunition. Therefore, having stopped all firing and delegated clearing of other firearms so that he could attend to casualties, he took a deliberate decision to have the firearm and ammunition photographed in situ then carefully moved to his vehicle which he was using as a first-aid point, so that he could oversee the firearm while continuing casualty care.

20. After the initial casualty assessment, and having arranged that the emergency services be contacted, *C* took a deliberate and considered decision to use private vehicles to move the casualties rather than wait for ambulances.

21. The NRA considers that these decisions were reasonable exercise of judgment by the RCO in the circumstances, and that because the decisions gave effect to the intent of Range Standing Orders that casualties be evacuated to medical care promptly and that evidence be preserved, the decisions were correct.

Actions subsequent to closure of the range.

22. *D*'s firearm and ammunition were transferred temporarily to a Registered Firearm Dealer. However, subsequent discussion included officers of *Police Force*, and because of uncertainties as to the legalities of various possible actions to secure the firearm and ammunition, those officers took possession of the firearm and ammunition. That was one of at least four available legal courses of action; since it secured the firearm and ammunition and preserved the evidence, it was a reasonable decision.

[30] Enclosure 2 *not included in redacted version*
[31] Enclosure 4 *not included in redacted version*

Conclusion

23. At about *time* on *Saturday in Spring* 2014, at *UK Military Ranges*, *D, E and F* were injured when *D*'s Krag-Jorgensen rifle suffered a catastrophic failure as he fired the fourth round of a practice. Technical investigation indicates that

    - the most likely cause of the failure was the rupture of the cartridge case of a round of homeloaded ammunition when fired
    - the rupture most likely occurred because of some combination of excessive pressure, weakening of the case and unsatisfactory fit of the case in the firearm, although it is not possible to determine which of these factors were present and in what proportion they contributed
    - *Detail redacted*
    - Excessive pressure could have been generated by a known but rare and improperly understood phenomenon associated with the propellant charge being significantly smaller in volume than the cartridge case
    - *Detail redacted*
    - *Detail redacted*
    - Following the case rupture, the firearm may have failed because of resulting excessive load, or because of a latent defect reducing its ability to resist a load that would otherwise have been inconsequential.

24. In the nature of the accident, the precise cause cannot be conclusively determined.

Observations

25. *Observation on range sharing arrangement redacted.* This administrative anomaly did not affect the insured status of members of either club, nor did it have any bearing on the accident. It is understood that MoD have already acted to prohibit the practice of range sharing other than with explicit permission in accordance with the Licences issued to civilian clubs.

26. The RCO, *C*, deviated from orders and procedures in dealing with the outcome of the accident. This deviation was a proper exercise of his judgment in the circumstances and an appropriate use of his authority as RCO.

27. It is understood that MoD have addressed uncertainties in the legal options for taking possession of privately-owned firearms following an occurrence through the recent revision of JSP403, the Manual of Defence Land Ranges Safety.

Recommendations

28. It is recommended that:

Disciplinary recommendations redacted.

a. The NRA publish a reduced and redacted version of this report, but including the redacted version of *LSI* report in full, so as to advise owners of Krag-Jorgensen rifles of the technical background to this accident.

b. The NRA require all members owning Krag-Jorgensen rifles fitted with replacement barrels, other than those replacements carried out under the current owners instructions and bearing a proof mark issued under CIP regulations or by one of the UK proof houses, to have the rifle checked by a competent gunsmith before it is used under the auspices of the NRA.

c. Subject to the above, MoD and NRA consider lifting the prohibition on use of Krag-Jorgensen rifles imposed following this accident.

<original signed>

Technical Investigations Co-ordinator
National Rifle Association

Enclosures:

1. Accident at *UK Military location Spring* 2014 – Photographs *redacted version included*
2. Land Incident Report (INCREP) *not included in redacted version*
3. Submission by *D not included in redacted version*
4. Documents forwarded by Training Safety Officer *UK Military location not included in redacted version*
5. History of Krag rifle *not included in redacted version*
6. Report by *LSI* dated 16 February 2015 – *Redacted version included*
7. *Document not included in redacted version*
8. *Document not included in redacted version*

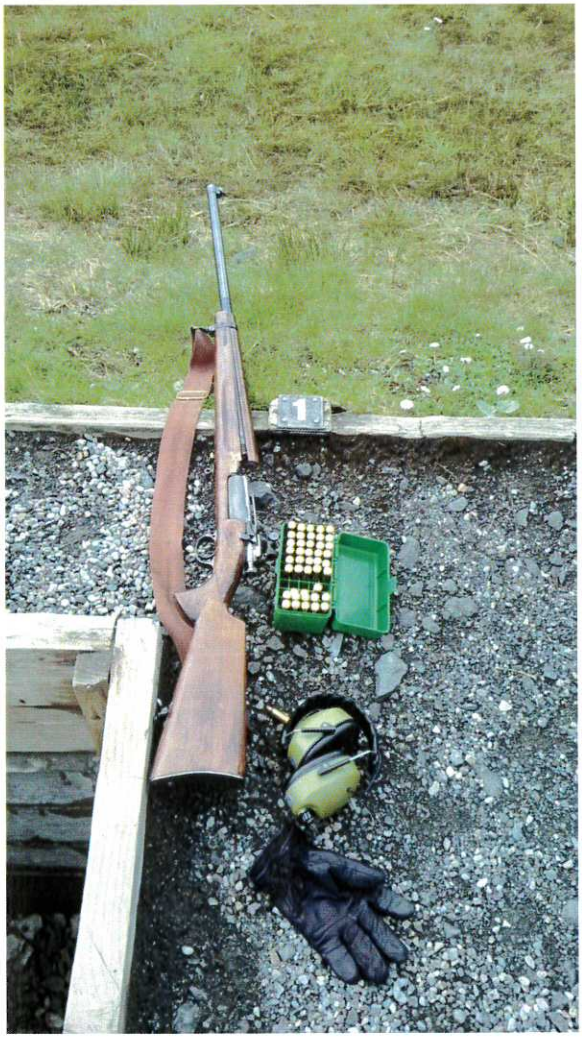
This redacted report for public release.

Full report distribution:

Senior Military Officer	DIO Trg Safety 1
AJ Mercer	NRA Chief Executive
NRA Trustee	Chairman NRA Disciplinary Committee
Officer Commanding	MoD Land Accident Investigation Team
MoD Employee	Secretary Defence Land Ranges Safety Committee
Senior Police Officer	Firearms Licensing Department, *Police Force*
MoD Employee	Training Safety Officer, *UK Military location* Training Camp
Local Government employee	Environmental Health department, *County* Council
C	*Official of RCA*
Civilian	*Official of RCB*
D	
E	
F	

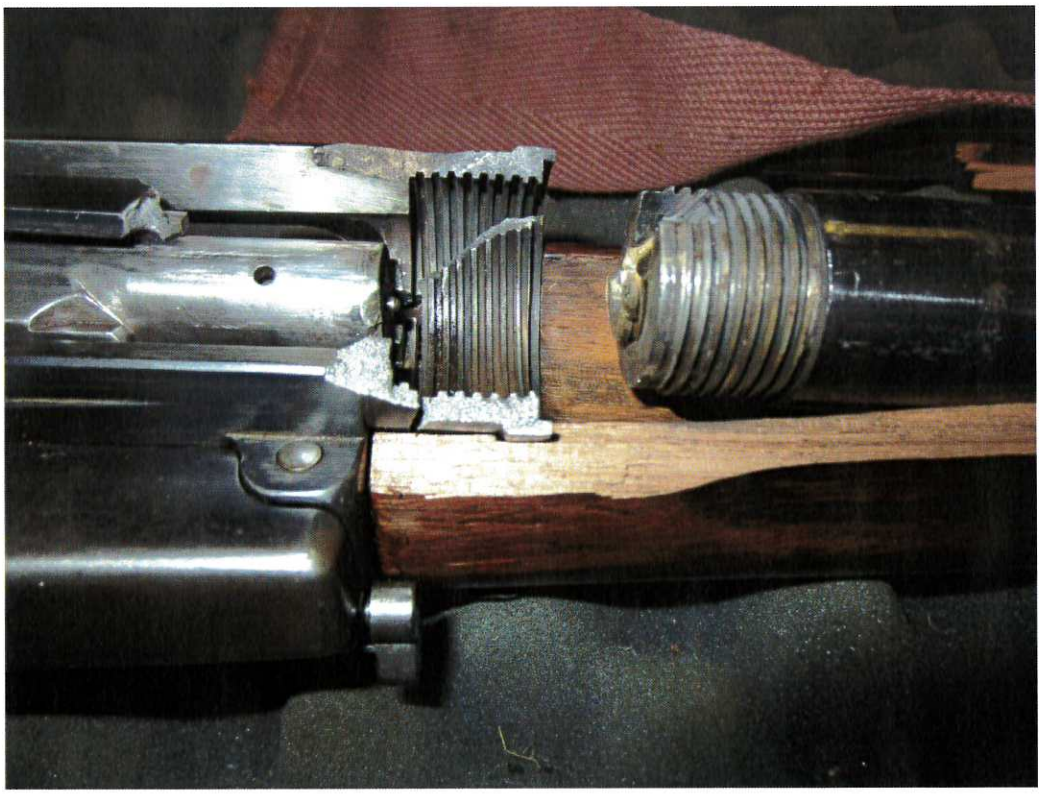
ACCIDENT AT *UK MILITARY* RANGE *SPRING* 2014 – PHOTOGRAPHS

Photoset 1 – firing point



Photograph 2 – Krag-Jorgensen rifle, ammunition and accessories at No1 fire pit shortly after the accident.

Photograph 3 – No1 fire pit open



Photograph 4 – Krag-Jorgensen rifle after the accident. Two parts of the receiver ring in the centre of the photograph, broken end of the extractor upper left, barrel with ruptured case in the breech right.

Photoset 5 – examples of fragments of wood from the stock located around No1 fire pit.

Photograph 6 – ammunition box showing live rounds and fired cases recovered after the accident, and label indicating the bullet weight and powder load.

Photograph 7 – Round of ammunition from ammunition box, inserted in a case gauge, which mimics the shape of the rifle chamber. Note the bulge in the neck of the case (1) preventing the shoulder of the case (2) from contacting the gauge.

PURPOSE OF EXAMINATION

1) I have been asked to examine the action of a Krag-Jorgensen rifle to determine if there was any physical or mechanical defect present that may have contributed to the catastrophic failure of the rifle action.

EXAMINATION AND RESULTS

2) The component parts of a Krag-Jorgensen bolt action rifle were present inside a padded gun slip. The parts present are shown in Figure 1 and included:

- A brown-colour varnished wooden stock with the major parts of the action still attached;
- A heavy match-grade barrel, threaded at the breech end;
- The lower section of the receiver ring;
- The left side of the receiver ring and receiver body;
- The fore sight hood;
- Carrying strap with rear barrel band and swivel attached;
- Three sections of brown-colour varnished wood from the hand guard and fore stock.

Figure 1 – Submitted components of a Krag-Jorgensen rifle

Condition

3) Apart from the damage associated with the catastrophic failure (discussed in detail in the following sections), the action, barrel and stock were in good condition and appeared well maintained. The action and barrel were largely free from signs of corrosion and showed wear commensurate with normal use. The barrel was not that originally fitted to this firearm and I understand that it had been replaced sometime circa 1950. The stock also showed signs of alteration from its original condition. The brown-

coloured varnished finish appeared hand applied and chequering on the semi-pistol grip and the underside of the forestock were crude. Furthermore, it appeared that the pistol grip and comb may have been replaced at some time due to the joins in the wood being visibly coarse, as shown in Figure 2.

Figure 2 – Pistol grip and stock showing possible alteration marks

Marks [1]

4) The serial number '32513' was impressed onto numerous parts of the rifle action, including:
   - Left side of the receiver ring (accompanied by a crown over a 'M P' stylised monogram);
   - Left side of the trigger guard;
   - Bolt guide rib;
   - Interior surface of the left side magazine cover;
   - Magazine follower;
   - Underside of cocking piece.

5) Furthermore, the number '325' was visible on the front surface of the safety lever. Wear on this surface may indicate that the remainder of the number had been obliterated at some time.

6) The bolt handle was also marked but with the number '7297' with a crown marked above it. The exterior surface of the lower section of receiver ring also bore the marks '3' and 'JP'.

7) The serial number and combination of these marks indicates that this rifle was originally from a series of rifles produced for the military at Steyr in 1897. Furthermore, the 'M P' monogram was the inspection mark of Jakob Maximillian Gran Paaske, who was head of the Norwegian inspection team at the Steyr factory between 1896-97.

[1] Norske Militærgeværer etter 1867, Karl Egil Hanevik, ISBN 82-993143-1-3

8) This is further supported by the markings on the bolt handle, with only those produced at Steyr being marked with a crown. It is reported that the bolt handles from Steyr and Kongsberg manufactured actions were not readily interchangeable.

9) Markings were also present on the barrel, including:

- Crowned 'K' and 'SP' on the chamber;
- 'YY 12' on the barrel wall;
- 'A' in the slot on the underside of the chamber.

10) The crowned 'K' was the Kongsberg factory mark, indicating it was produced and tested there, and the 'SP' referred to the type of steel used in the barrel manufacture. 'YY 12' indicated the steel producer and was seen on barrels made between 1948-50. Furthermore, the 'A' monogram was the inspection mark of Halfdan Alstad, who worked at Kongsberg between 1945-50. It therefore suggests this barrel was manufactured at Kongsberg between 1948-1950.

11) I understand that thousands of these match-grade barrels were produced at Kongsberg for the conversion of Krag-Jorgesen rifles. However, these conversions were not always done by professional gunsmiths to high standards, which led to a series of catastrophic rifle failures in the 1950s.

Damage

12) The rifle had suffered a catastrophic failure resulting in significant damage to the action and minor damage to the forestock in the vicinity of the cartridge chamber. The chamber itself was intact and there was no visible bulging anywhere along the length of the barrel. The rifled section of the bore was clear of obstructions but a small amount of debris was visible.

13) However, a ruptured cartridge case was still present within the chamber. The upper portion of the case head and primer cup were missing, with the remaining portion of the head exhibiting extensive plastic deformation resulting in almost complete separation from the case body. The remaining section of the head was protruding rearward out of the chamber. The chamfered recess at the top of the barrel to accommodate the extractor claw was also visibly deformed, particularly on the left side, as shown in Figure 3a and 3b.

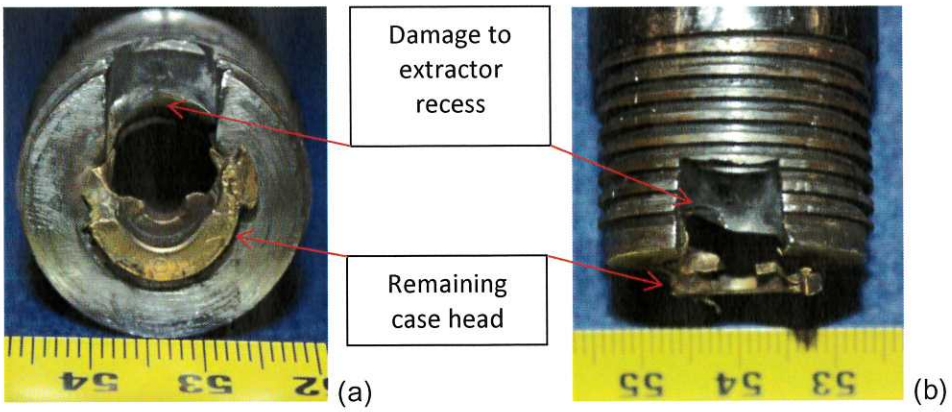


Figure 3 – (a) Ruptured cartridge case head, and (b) deformation to extractor recess

14) The front portion of the receiver had suffered extensive damage resulting in the separation of the receiver ring and the left side of the receiver from the receiver body, as shown in Figure 4. The left side piece and the lower portion of the receiver ring were present, shown in Figure 5 (a) and (b), respectively; however, the upper / right sections of the receiver ring were missing.

Figure 4 – Failed receiver

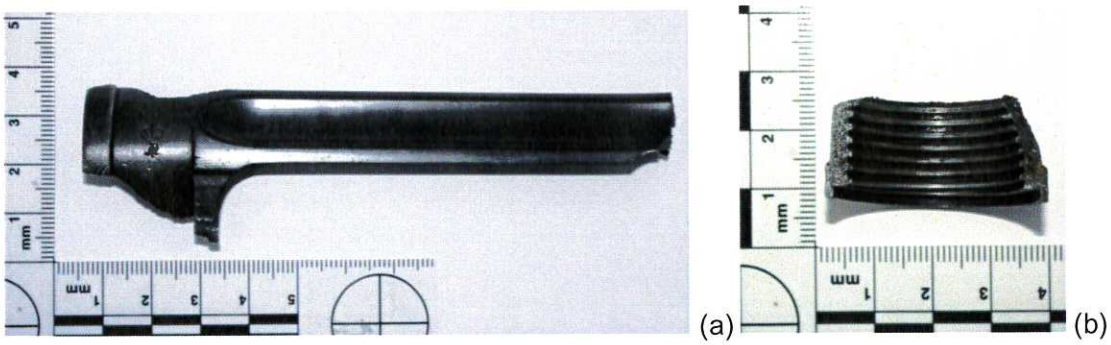
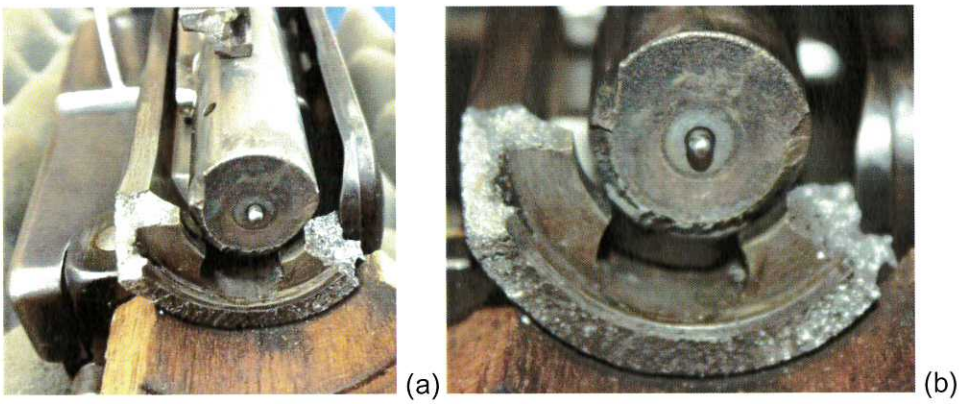


Figure 5 – (a) Left side of receiver/receiver ring, and (b) lower part of receiver ring

15) Furthermore, the front portion of the extractor was missing, shown in both Figure 4 and Figure 6 (a), with a fracture surface visible approximately 25 mm back from the bolt

face. Damage was also present along the edge the bolt face that appeared to be the result of the complete shearing away of the cartridge head control rib, shown in Figure 6 (b). Accompanying this damage was discolouration of the fracture surfaces on the bolt face and lower part of the receiver, and apparent soot deposits along the upper part of the bolt body.

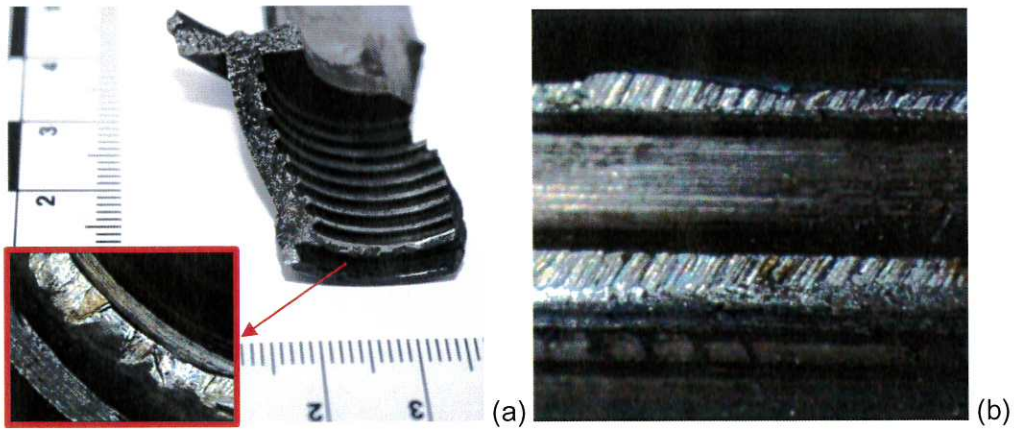


(a) (b)

Figure 6 - (a) Fracture surfaces of the front section of the receiver, and (b) fracture surfaces on the bolt face edge (note the discolouration on the bolt and the bolt face).

16) Macroscopic examination of the front face of the left side of the receiver ring showed strike marks visible on the first screw thread, as shown in Figure 7(a). These marks extended onto the top surface of the second thread producing coherent striations, as shown in Figure 7(b). These strike marks appeared to have been created by a flat faced object with straight sides, such as a screw driver tip or punch, and due to the coherence of the striations between screw threads they could not have been deposited when a barrel was fitted into the receiver ring.

17) Closer inspection of the screw threads on the receiver ring sections indicate that the first thread from the front to have been partially removed at some time, reducing its thickness by approximately half, as shown in Figure 8. Furthermore, numerous cut marks were visible on subsequent thread walls, which may have been as a result of attempts to alter the thread width or depth, shown in Figure 9.



(a) (b)

Figure 7 – (a) Strike marks on front surface of screw thread, and (b) concurrent striations on thread surfaces

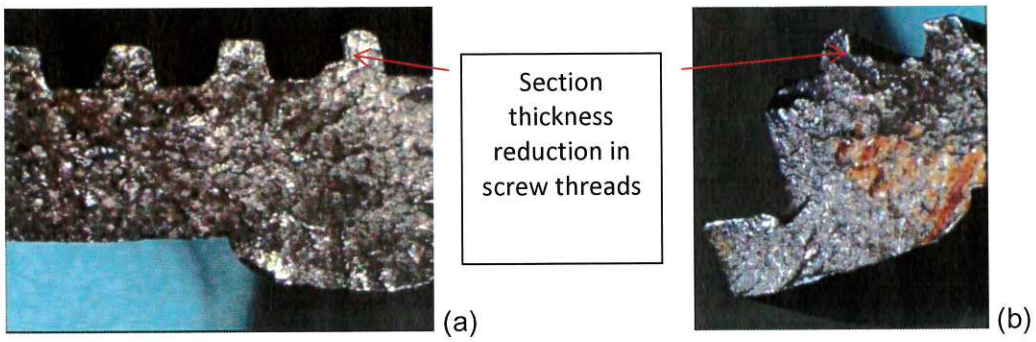


Figure 8 – Cross section view of first screw threads from (a) left side of receiver ring, and (b) lower receiver ring.

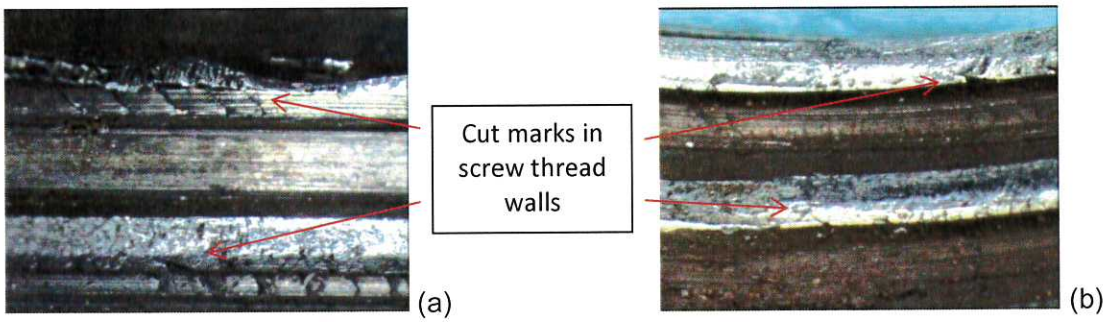


Figure 9 – Cuts in screw thread walls on (a) left side of receiver ring, and (b) lower receiver ring.

18) Furthermore, on the exterior surface of the left side and lower receiver ring sections were a series of uniform impressed marks, as shown in Figure 10. These marks may have been the result of this area being struck by another object or due to compression by another surface, such as being clamped in a vice or similar holding device.

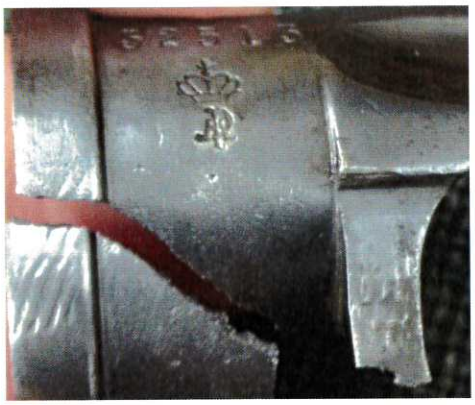


Figure 10 – Impressed marks on exterior of receiver ring

19) The presence of these marks may indicate that alterations have been performed on the rifle action at some time and the work may have been undertaken by an inexperienced or amateur gunsmith.

Failure surface analysis

20) The fracture surfaces of the lower and left side of the receiver ring were examined using optical and scanning electron microscopy (SEM) to establish the mode of fracture and determine if there were any failure initiation sites.

21) Microscopic examination of the fracture surfaces showed a faceted surface topography associated with trans-granular cleavage, as shown in Figure 11. Although commonly associated with brittle fracture, this type of failure occurs in many types of metal, including many steels, when deformed at very high strain rates. All of the fracture surfaces examined exhibited this type of fracture surface.

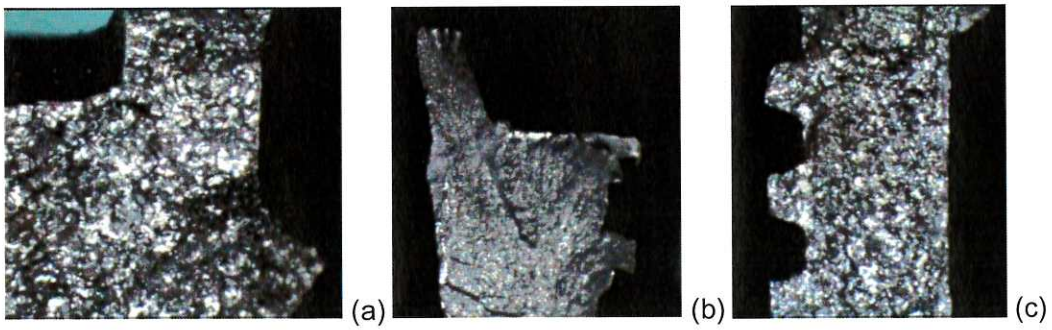


Figure 11 – Fracture surfaces of (a) lower surface and (b) upper surface of the left side of the receiver, and (c) the right side of the lower section of the receiver ring

22) No areas characteristic of fatigue crack initiation and growth were observed on the submitted pieces; however, this does not entirely exclude fatigue as a failure mode.

23) During the examination of the fracture surfaces two areas were selected for detailed examination. The first area, as previously mentioned, was the fracture surface between the lower section of the receiver ring and the receiver body. These surfaces were discoloured (see Figure 6) when compared to the bright fracture surfaces present on most other parts examined. However, on microscopic examination no obvious crack initiation site(s) were observed. A second discoloured area was observed along the upper section of the left side of the receiver, as shown in Figure 12. It can be seen that along with a darkening of the fracture surface, a brass coloured mark was also observed adjacent to a screw thread located toward the rear portion of the receiver ring.

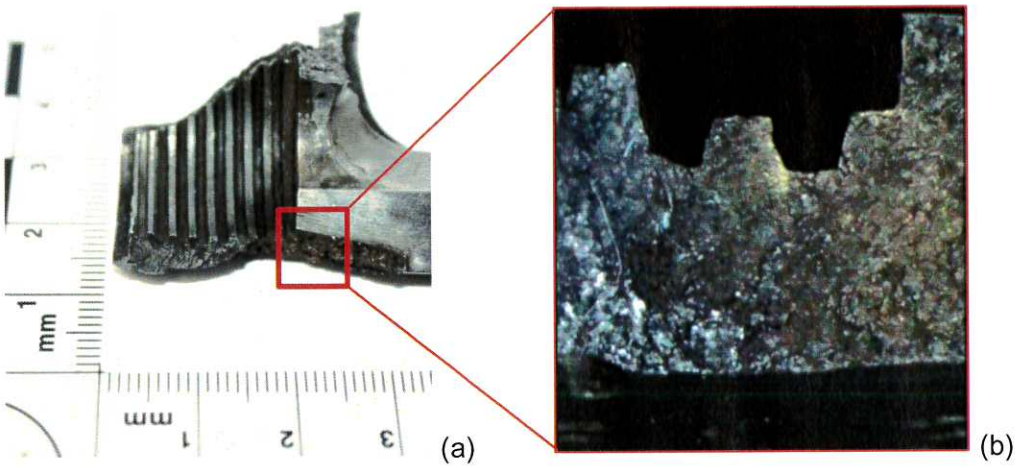


Figure 12 – (a) Upper fracture surface of the left side of the receiver, and (b) close-up showing the brass-coloured discolouration

24) SEM and elemental analysis was conducted in this area, as shown in Figure 13. The cleavage fracture surface can be clearly seen and the elemental analysis shows the presence of copper and zinc, as well as lead, barium, silicon, potassium, calcium and aluminium. The source of the copper and zinc could be the cartridge case alloy and the lead, barium, silicon, calcium and aluminium could have come from the primer compound i.e. elements present in the primer have condensed onto the fracture surface, although the exact primer formulation used was unknown.

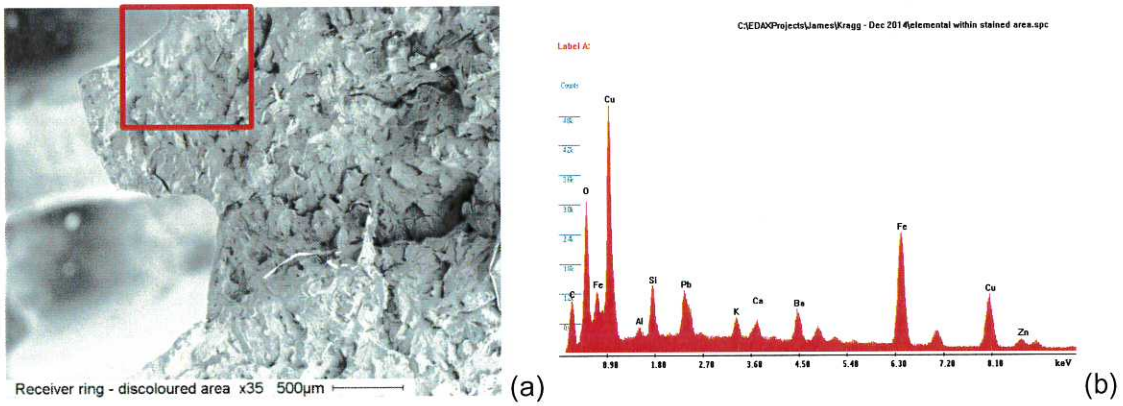


Figure 13 – (a) SEM image of discoloured fracture surface, and (b) corresponding elemental composition

25) Detailed examination of this area also revealed secondary cracking of the screw threads immediately below the fracture surface, as shown in Figure 14. It can also be seen that the smaller of the cracks appears to be emanating from a notch cut into the wall of the thread. Other notches in the walls of the screw threads were seen across the threaded parts but no other cracks were observed.

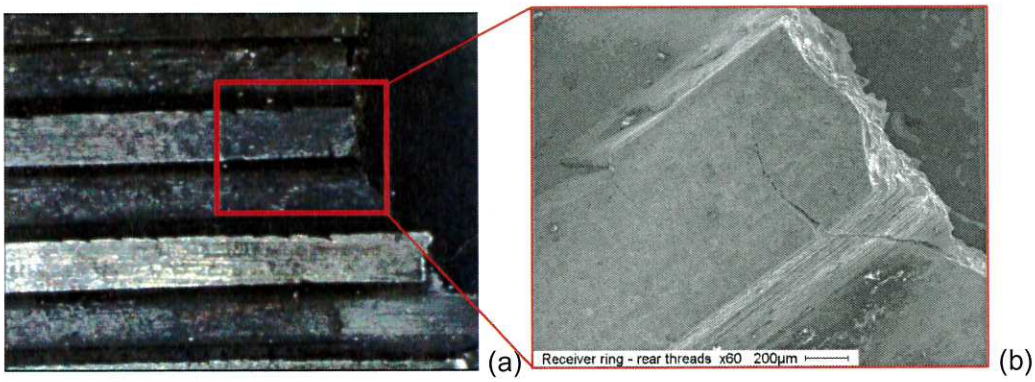


Figure 14 – (a) optical image of cracks in the screw threads, (b) SEM image of the same area

26) Chemical analysis of the fracture surfaces toward the front of the receiver ring showed a different composition, with lead present as the primary contaminant, as shown in Figure 15. This is likely to have originated from vaporisation of lead from the bullet base as well as lead residues present in the barrel bore from previous firings.

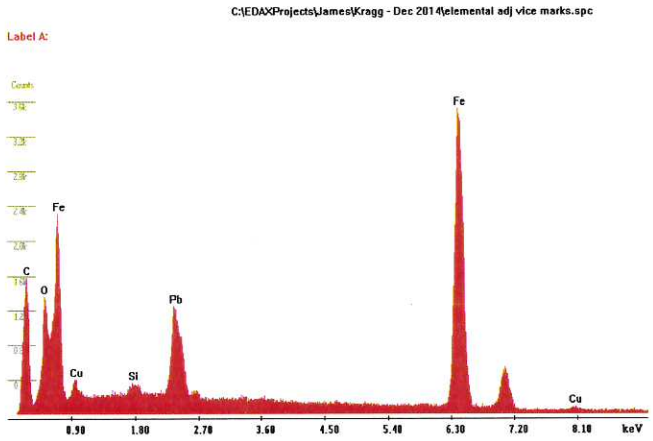


Figure 15 – Chemical composition of fracture surface at the front of the receiver ring.

Materials analysis

27) Due to the good condition of the rifle action it was decided that there was no indication that the rifle had been subjected to detrimental service or storage conditions that could have adversely affected the material properties of the steel. Furthermore, due to the nature of the fracture surfaces it would have been necessary to remove material from these areas for testing, which would have precluded any future examination of these surfaces, if necessary. As such, no material analysis or mechanical testing was performed as part of the current investigation.

Cartridge case

28) A fired 6.5x55 mm Norma cartridge case was also submitted, shown in Figure 16. Nothing remarkable was observed about the case, with no signs of bulging or excessive stretching along the case walls or around the base. The primer cup was not protruding

from the pocket and showed no signs of excessive flow. This indicated that there were no obvious headspace issues at the time this cartridge was fired. The only unusual feature was a small area of deformation on one side of the case mouth (circled), causing the mouth rim to appear slightly undulated.

Figure 16 – Norma 6.5x55 mm fired cartridge case (insert: headstamp)

Interpretation

29) As a result of the visual and microscopic examinations performed on the items submitted, no failure initiation site(s) were positively identified on these parts and all fracture surfaces examined had a similar faceted appearance. From just these parts it would be determined that the most likely mode of fracture was cleavage as a result of single overload event. However, as the top section of the receiver ring was not recovered after the incident it is not possible to exclude that this section could have contained evidence of a flaw that could have initiated the failure of the rifle action.

30) Loss of the front section of the extractor, the cartridge rim control rib on the bolt face and the top section of the case head support the view that excessive pressure emanated from the chamber. As the extractor recess in the top of the barrel acts as a weak point in the system, the excess pressure would act on the extractor claw driving it into the upper section of the receiver ring, which may have initiated a crack at some location in the receiver ring. Due to the extremely high rate at which pressure is applied to the action during firing, once crack initiation occurs, propagation to failure would be almost instantaneous.

31) It was observed that cuts were present in the walls of the screw threads in the receiver ring. It cannot be excluded that one or more of these could have acted as a crack initiation site, as demonstrated by the presence of a secondary crack emanating from one of these cuts on the left side of the receiver ring (see Figure 14).

32) Discolouration of the fracture surfaces on the left side and the lower aspect of the receiver ring indicate that these fracture surfaces were exposed to the gases generated during firing. Discolouration of the fracture surface may indicate the presence of a pre-existing crack in these areas; however, the extent of the discolouration indicated that these surfaces were subsequently exposed to the gases escaping from the ruptured case. Furthermore, the presence of metallic residue on the fracture surface on the left

side of the receiver indicated that this could have been deposited as a result of case head failure, meaning this small area of fracture surface would have had to have been exposed as the case head was rupturing.

Conclusion

33) From the examination of the components parts of the failed Krag-Jorgesen rifle, serial number 32513, no definite cause of failure could be established. The evidence observed provides support to failure being as a result of a single overload event; however, the upper part of the receiver ring was not recovered after the failure and as such could not be examined. It is therefore not possible to exclude that this section of the action did contain an flaw that led to the catastrophic failure of the rifle.

Date of Issue: 16 February 2015